1.2.20. THE INDUCTANCE OF MATRIX EDDY-CURRENT TRANSDUCERS CALCULATION OF MOVINGS

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The matrix method of the eddy-current control means the placing exciters of the electromagnetic field, which are used as magnetic unit modules – inductance coals, above the object of the control in space. The error free performance of the transducers is possible, when the inductance coals are set above the object of the control with a maximum gap of safety $h_{z\text{н}}$.

The problem of the development the matrix eddy-current transducers (MECT) was solved by unilateral tolerance to the object of the control to provide the noncontact inspection vertical h_z, horizontal h_y moving components and width of the object of the control b_r by the count it's profile features. The increasing of a controlled factor quantity leads to the proportional increasing of the number of the MECT's modules and it makes difficult to place them above a size – limited surface of the object of the control. It's necessary to use the integral technologies, which allow getting the thin-film MECT's constructions. This idea is easy actualized by the current elements layering along the surface of a band magnetic conductor (its thickness is tens micrometers) [1].

To define the magnetic flows of the MECT's modules is not easy, because of the three-dimensional mode of the electromagnetic field. Also it needs to determine limits of the constructively unrestricted quasi-stationary fields of the in-phase current elements, that troubles the using of the familiar software products (ANSYS, Elcut and others), which are meant to calculate the two-dimensional fields. The three-dimensional magnetic field of the MECT's modules demands to develop a new numerical method of the inductance computations [2]. At this computation it was used the finite-element method, which consists in the fragmentation the closed circuit to the separate parts (pieces of line conductors with infinite small section) – current elements (CE). It is convenient to view the magnetic flows of the each CE by way of totality of elementary small section tubes, inside which the magnetic intensity $\vec{H}$ is constant. This magnetic intensity $\vec{H}$ in the section $\Delta S_m = \Delta b_m \Delta h_z$ is solved by the integration the Bio-Savar-Laplas equation $d\vec{H} = I_\text{к} d\vec{b}_m \times h_0 \big/ 4\pi |h|^3$ for CE $I_\text{к} d\vec{b}_m$, which is distanced from the verification point of $\vec{H}$ on h. The width and height of the elementary magnetic flow tube are $\Delta b_\text{м}$ and Δh_z. The limit's definition of the constructively unrestricted quasi-stationary fields of the in-phase CE is well grounded [3]. The magnetic flow, which determines the initial module inductance $L_\text{н}$, was calculated by the summation of the tubes magnetic flows. Numerical calculations $L_\text{н}$ is the sum of the magnetic flows of the tubes $\Phi_{i_s} = \mu H_{i_s} \Delta S_m$, which are created by *i*-th CE, and the magnetic flows of the tubes $\Phi_{ij_m} = \mu H_{ij_m} \Delta S_m$, which are created by *j*-th CE and covered *i*-th CE

$$L_\text{н} = \sum_1^{n_x} \left(\sum_1^{m_{z_i}} \sum_1^{m_{y_i}} \Phi_{i_s} + \sum_1^{n_x n_y} \sum_1^{m_{z_{ij}}} \sum_1^{m_{y_{ij}}} \Phi_{ij_\text{м}} \right) \Bigg/ I_\text{к} ,$$

where n_x, n_y – the quantity of current elements of the discrete current tire in the direction of the axes X and Y; m_z, m_y – the quantity of tubes of magnetic flux in the direction of the axes Z and Y. The working inductance L_p is determined $L_p = L_н - L_{вн}$, where $L_{вн}$ – change of inductance of modules of the matrix eddy-current converter from the influence of the fields of eddy currents on the surfaces of the object of the control ($-L_{vn}$) and changes of the magnetic streams of free current elements ($+L_{vn}$).

For check of the reliability of the received theoretical results the computerised laboratory stand for definition of characteristics of modules matrix eddy-current transducers is created. The stand includes the tool microscope MMI-1, the matrix eddy-current transducers, the electronic block of formation of output signals and software for their automatic processing. Models of object of the control are fixed on the subject table MMI-1, so that the controllable surface $X_rO_rY_r$ is located in the parallel working plane XOY of the matrix eddy-current transducers. And its centre coincides with axis Z_c of rotation of a table. The initial installation of the object of the control $h_y = 0$, $h_z = h_{zн}$, $\varphi_x = 0$ is provided with the combination of the axes of the coordinates the matrix eddy-current converter and the object of the control. The electronic block of formation of the output pressure carries out transformation of an analogue signal of the modules of the matrix eddy-current converter to the digital form and transfers a vector of measuring pressure in the computer.

The received characteristics $L_{vn} / L_{vnm} = f(h_y, h_z)$ of the strongly coupled modules of the matrix eddy-current transducers essentially differ from characteristics of the weakly-connected modules. The analysis of characteristics of the strongly coupled modules of the matrix eddy-current converter shows, that for the converters which are outside of the object of the control, $L_p > L_н$ ($+L_{vn}$). It is possible to explain a given result to those that the indemnification of exciting fields of the closed modules of the matrix eddy-current converters by the fields of the eddy currents of object of the control at $h_z \to 0$ reduces their magnetic stream that reduces pressure on the magnetic stream of the next open module. In this case the strong increase in the section S_m of a magnetic stream of the open module leads to its growth L_p ($+L_{vn}$), that allows to draw a conclusion on dominating influence of the changes S_m to the value L_p and necessities of delimitation of a structurally unlimited quasi-stationary fields of the in-phase current elements.

Comparison of the theoretical and experimental characteristics of modules of matrix eddy-current transducers has shown their satisfactory coincidence that testifies to reliability of the received results.

References:

1. **Merkulov A.I.** About the similarity of the constructions of the parametric additional electromagnetic converters // Devices and control systems. – 1992. – N 8. – P. 20 – 23.
2. **The decision** on the delivery of patent for the useful model by the application № 2008125730/22(031299)RF, G 01B7/00, G 01N27/90. The diagram of the work of the electromagnetic control with the matrix converter / A.I. Merkulov, A.U. Lavrov, B.A. Merkulov.
3. **Lavrov A.U.** The electromagnetic transducers for devices of quick-test geometry and relative position rail. Abstract of Ph. D. thesis. – Samara, 2008. – 20 p.